

FINAL TECHNICAL REPORT
ONR GRANT #N00014-91-J-1242John A. Barth
Buoyancy-Driven Coastal Currents

The stability of a coastal upwelling jet and front was investigated using the primitive equations applied to a continuously stratified flow in geostrophic balance (Barth, 1994). A linear stability analysis explained the growth of two modes of instability with distinctly different horizontal scales. A long-wavelength mode (fastest-growing wavelength of $O(100 \text{ km})$) was a modified version of a traditional baroclinic instability. A second, rapidly growing frontal instability was also found and had the following properties: fastest growth at short wavelengths ($O(20 \text{ km})$); e -folded in less than 1.5 days; propagated rapidly in the direction of the mean flow. The frontal mode was trapped to the surface front and its influence was confined to the upper water column ($z \lesssim 70 \text{ m}$). A significant subsurface vertical velocity maximum (20 m d^{-1} at 30 m) was associated with the frontal instability. The linear stability predictions were verified by and compared with results from a time-dependent, three-dimensional, nonlinear ocean circulation model.

The linear stability analysis was also applied to observed sections of salinity and velocity from the buoyancy-driven Alaska Coastal Current (Barth, 1994b,c). Again, two modes of mesoscale variability were found. One unstable mode represented a modified form of traditional baroclinic instability with fastest-growth (e -folding in 1.8 days) occurring at 63 km with a slow phase speed (0.09 m s^{-1}) in the direction of the mean flow. A second unstable ageostrophic, frontal instability mode had a fastest-growing wavelength of 40 km that e -folded in 2.3 days and propagated rapidly (0.57 m s^{-1}) in the direction of the mean flow. A three-dimensional, time-dependent, fine-resolution numerical ocean circulation model was used to study the nonlinear evolution of the unstable buoyancy-driven coastal jet. Early in the simulation, short-wavelength frontal instabilities grew and propagated along the jet. Eventually, the frontal instabilities were frictionally damped and the long-wavelength baroclinic instability became dominant. The wavelength (65 km) and phase speed (0.09 m s^{-1}) were in excellent agreement with linear predictions. The baroclinic instability amplified into a series of backward-breaking waves whose crests eventually pinched off to form fresh, anti-cyclones while saline cyclones remained in the troughs. The scales of these eddies (diameters of 40 km) were consistent with those evident in maps of dynamic height from the Alaska Coastal Current. Vigorous vertical velocities, as large as 25 m day^{-1} , associated with the unstable meandering coastal current were noted to be potentially important for the vertical flux of material into the euphotic zone in the Alaska Coastal Current.

Density and velocity data from a high-resolution, upper-ocean survey in the California Current using SeaSoar and a shipboard acoustic Doppler current profiler were used to diagnose vertical velocity via the quasigeostrophic omega equation (Shearman *et al.*, 1998). The diagnosed vertical velocity field showed velocities of $30\text{--}40 \text{ m d}^{-1}$. The lateral distribution of relative vorticity and vertical velocity was characterized by patches with length scales of $20\text{--}30 \text{ km}$. Geostrophic streamline analysis of vertical velocity indicated that water parcels made net vertical excursions of $20\text{--}30 \text{ m}$ over $2\text{--}3$ days, resulting in net vertical velocities of

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June 22, 1998

Dr. Thomas H. Kinder
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Dear Dr. Kinder,

In order to complete my ONR grant entitled "Buoyancy-Driven Coastal Currents", I am sending three copies of the *Final Technical Report* to you with copies distributed as indicated below, along with a completed *Report Documentation Page (SF 298)*.

Sincerely,

Dr. Jack A. Barth
Associate Professor

Enclosures

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10-15 m d⁻¹. Water parcels moving along geostrophic streamlines experienced maximum vertical velocities in regions of maximum alongstream change in relative vorticity, an indication of potential vorticity conservation.

LIST OF PUBLICATIONS

- Barth, J. A., 1994a. Short-wavelength instabilities on coastal jets and fronts. *J. Geophys. Res.*, **99**, 16095-16115.
- Pierce, S. D., J. A. Barth and R. L. Smith, 1998. Improving ADCP accuracy with WADGPS and adaptive smoothing of ship velocity. *J. Atmos. Oceanic Technol.*, submitted.
- Pierce, S. D., R. L. Smith, P. M. Kosro, J. A. Barth and C. D. Wilson, 1998. Continuity of the poleward undercurrent along the eastern boundary of the mid-latitude north Pacific. *Deep-Sea Res.*, submitted.
- Shearman, R. K., J. A. Barth and P. M. Kosro, 1998. Diagnosis of the three-dimensional circulation associated with mesoscale motion in the California Current. *J. Phys. Oceanogr.*, in press.

Abstracts:

- Barth, J. A., 1992. Ageostrophic, short-wavelength instabilities on coastal jets and fronts. *Eos, Transactions, American Geophysical Union*, **72(51)**, 50.
- Barth, J. A., 1994b. Mesoscale variability generated by an unstable buoyancy-driven coastal current with application to the Alaska Coastal Current. *Eos, Transactions, American Geophysical Union*, **75(3)**, 133.
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- Shearman, R. K., J. A. Barth and P. M. Kosro, 1996. Diagnosis of three-dimensional circulation: Results from the Eastern Boundary Current program. *Eos, Transactions, American Geophysical Union*, **77(3)**, Ocean Sciences Meet. Suppl., OS131.
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